III. Making Beer

The brewing industry follows processes and methods that have remained essentially unchanged for centuries. Technology has contributed primarily to achieving more consistent quality in the final product, rather than changing the actual process of brewing beer. Microprocessors and computer systems allow the brewer to precisely monitor and control brewing operations.

Many brewhouses have been modernized with sophisticated control equipment. Instrumentation and control technology is available for the programmed mechanization of brewhouse processing from the weighing of raw materials through mashing to the production of wort. These installations feature "repeatability" and reliability. Of course, there is provision for brew house operator override whenever atypical conditions demand it. This brewhouse automation provides precise control of quantities, times and temperatures.

Although details of brewing vary from brewery to brewery, this discussion is designed to be a representative outline of brewing. For more detailed reading, refer to the latest edition of *The Practical Brewer,* published by the Master Brewers Association of the Americas. *The Practical Brewer* is the industry's source for brewing information.

Raw Materials

The basic ingredients used in brewing are water, barley malt, rice or corn (adjunct grains), sugar and syrups (liquid adjuncts), hops, and yeast. Other ingredients used in specialty brews include wheat, wheat malt, fruit, honey, and spices

Water

Of all the ingredients in beer, water is the largest in quantity. Since beer contains approximately 90% water, water quality is a major factor in determining beer type and quality. For centuries, breweries were located water quality was consistent. Often this water was drawn from underground sources where its composition was relatively constant and pollution-free. However, since water supplies are becoming polluted everywhere, brewers how must institute strict water quality control procedures. The water is conditioned as necessary to ensure uniform brewing results.

Brewing water must be potable; that is, free from disease producing organisms and substances producing adverse physiological effects (microorganisms and inorganic chemicals). It should also be clear, colorless, odorless, and free of objectionable taste.

Furthermore, the brewer has specific chemical requirements for good brewing water. It should possess a medium degree of permanent hardness. The requirements include a sufficient amount of calcium and magnesium and proper alkalinity in order to insure proper mash pH, proper hop extraction, good kettle break, sound fermentation, and proper flavor and color development in the finished beer.

Barley Malt

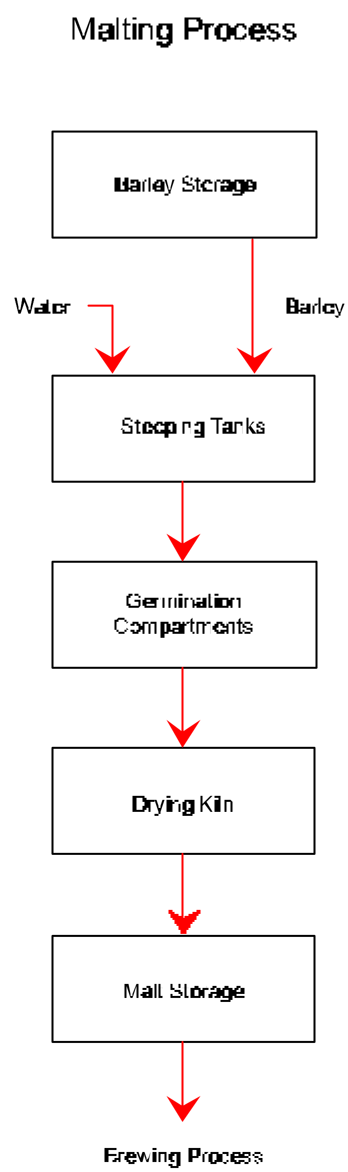
Barley, specially treated to become malt, is the primary ingredient in producing beer. A special type of barley is grown for the purpose of brewing, with the major growing area in the U.S. concentrated in the middle and northwestern states. Barley propagation has improved yield and quality, and research for new and improved varieties with high extract quality always continues. Barley is the preferred grain because it can be more easily malted for brewing purposes than any other cereal; the solubles extracted from barley malt are of a more desirable character and are more complete than those extracted from other grains.

The barley is turned into malt, either by a member of the associated malt industry or in the malthouse of a brewery. Some of the large brewers own their own malt plants. The brewing industry currently consumes more than 5 billion pounds of brewer’s malt annually.

The Malting Process

Malting is the first of three enzymatic systems involved in the production of beer. Malting is the controlled germination of barley during which enzymes are formed which will be used in the brewing process. In all phases of the malting process the complete control of temperature, humidity, and airflow is required. First, cleaned graded barley is steeped in water until the proper moisture content is reached. The steeped barley is then germinated for a few days under controlled conditions. When germination is complete, the green malt is dried and growth is stopped (kilning). After kilning, the sprouts are removed from the green malt by passing them over a malt cleaner. The malt is then stored for at least three weeks prior to shipment or use.

The malt contains less moisture than the original grain and is therefore more suitable for storing and grinding. The endosperm (the starch-bearing portion of the grain) is “mellow” rather than hard as in the original grain. Its ability to effect chemical changes (enzymatic values) is greatly increased. Malt has flavor and aroma and largely determines the character and quality of the beer by providing the basic flavoring materials, the majority of the fermentable extract, the proteins essential to foam, and all of the enzymatic activity during the mashing process.



The brewer judges malt quality by adherence to his malt specifications and its performance during the brewing process. The brewer's malt specifications are designed to ensure receipt of uniform malt shipments from all suppliers. These specifications differ from brewery to brewery, since they reflect the brewer's philosophy of brewing.

Adjuncts

Adjuncts - Adjuncts are non-malt carbohydrate materials which beneficially complement or supplement the principal brewing material (barley malt). The use of adjuncts in the manufacture of malt beverages is a distinct feature of American brewing practice. Adjuncts are used to obtain more extract at a lower cost, being cheaper than malt. Adjuncts also influence the composition of the wort. Use of adjuncts results in beers of lighter color, snappier taste, enhanced physical stability and superior chill-proof qualities. The major brewers generally do not produce malt beers since the adjuncts impart the qualities generally demanded by U.S. consumers in mass produced beers. However, many microbrewers produce a wide range of all-malt beers.

The non-malt brewing materials used in greatest quantity today are those derived from corn and rice, with corn being most common. Unlike the distilled spirits industry, which uses whole kernel cereal grains as basic ingredients, the brewing industry uses pre-processed cereal grains like corn grits and meal, corn flakes, refined corn grits, rice grits, and rice flakes. Sometimes barley, soybean, wheat and their products are also used. Liquid adjuncts include corn syrups, crystalline dextrose, and invert sugar-syrup.

Brewing adjuncts can be further classified into those added to the cooker or main mash tub and those added to the brew kettle. The mash adjuncts consist of cereal products like meal, grits, flour, flakes or dry starch. They supply starch that is converted into dextrins and fermentable sugars by the enzyme system of the malt. Kettle adjuncts consist of cereal grain syrups and sugars. These brewing syrups and sugars provide readily soluble extract, and some can give definite characteristics to the flavor of finished beers and ales. In addition, the use of these liquid adjuncts makes possible an increase in production in cases of limited brewhouse capacity.

Opinions vary considerably among brewers concerning the “correct” use of adjuncts. The types and amounts used by a particular brewer depends on their cost, the type of beer to be produced, and the brewer’s philosophy.

Hops

Hops are an agricultural crop uniquely associated with beer. The brewing industry used approximately 43 million pounds in FY 1994. Hops, as used in brewing, are the dried blossoms of the female hop plant. Hops are used primarily in dry form, baled or as hop pellets. Limited use is also made of hop extracts.

Hops give beer its distinctive taste and aroma. Although there is a difference of opinion as to the importance of hop variety and quality to final beer flavor, most brewers agree that specific hop characteristics are important for the production of specific types of beer.

Hops also play a part in beer quality. In the brew kettle, hops help to clarify wort (pronounced "wurt") by coagulating certain protein matter. They contribute to flavor stability and foam retention and assist in preserving the beer.

Brewhouse Operations

The objective of brewhouse processing is to produce quality wort from the raw materials efficiently. Wort is the aqueous solution containing the extract soluble and suspended substances derived from the ingredient materials. The wort is then used to make the beer.

Principal steps in wort production:

1. Preparation of raw materials
2. Mashing
3. Wort separation
4. Wort boiling with hops
5. Wort cooling

Preparation of Raw Materials

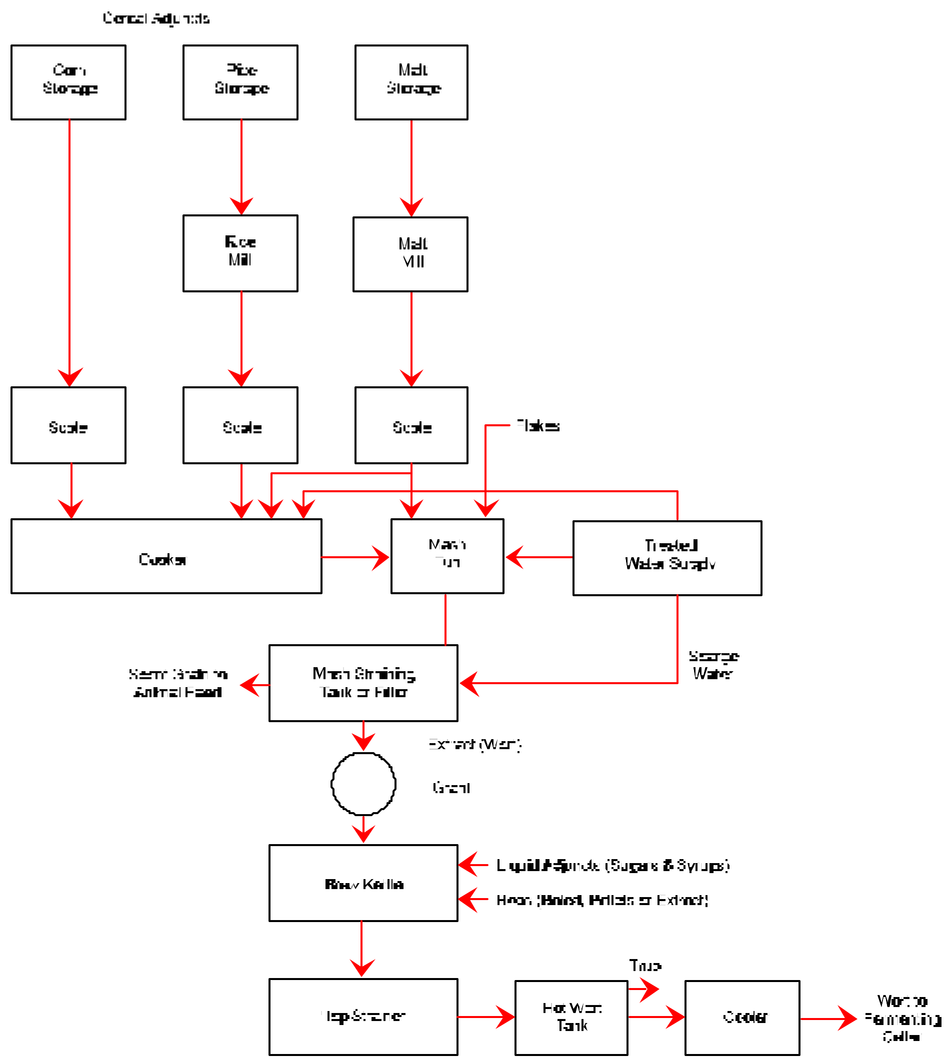
The malt and cereal adjuncts are transferred from the storage bins through a conveying system to the grain weighing system. The malt and raw cereal are cleaned either while being unloaded into bins or during transfer to the brewhouse. The conveying system should provide a reasonably gentle transfer of the malt to avoid shattering the husks, and should be dust tight to avoid the introduction of contaminants.

First the malt and adjuncts must be weighed. Weighing can be done incrementally or on a batch basis. A system for incremental or continuous weighing uses an automatic dumping hopper with an integrator and some means of recording and controlling the amount of grain being transferred. A batch weighing system uses a hopper which holds the amount of ingredients for a mash. A mechanical or electrical signal is used to determine the quantities on the scale hopper system.

Next, special multi-roll mills are used to crush the malt. The design of a malt mill for a specific brewery depends upon the nature of the malt to be crushed, the type of mashing vessels, and the method of wort separation. The husk is preserved in a larger particle size to a much greater degree for a lauter tub operation than is necessary for a mash filter. The grind for a Strainmaster operation is between these two. The objective is to reduce the malt to the smallest particle size consistent with the separation of wort.

The brewer frequently examines the crushed malt to ensure that the malt is being properly crushed; ideally, it would contain no uncrushed kernels. Brewery malt crushing splits the husk lengthwise to expose the endosperm. The malt husks, separated from the endosperm portion of the kernel, serve as a filtering medium at the end of the mashing process. The endosperm should be disintegrated to readily expose it to enzymatic action. There should be a minimum of crushed malt flour which will cause excessive dough in the mash.

Brewhouse Operations



Most cereal adjuncts are already preprocessed or refined to some degree, are highly soluble, and can be immediately put into the mash without milling. The one exception is rice. Some brewers prefer to mill rice to a finer particle size than the form in which it is transported and stored.

Mashing

Mashing is the second of the major enzymatic systems in the brewing process. The mashing process combines the ground malt and adjuncts with water in the proportion of one barrel of water for each 100 pounds of brewing materials. This dissolves the readily soluble substances in the ingredients. Most importantly, mashing permits the malt enzymes to act upon the insoluble substances to render them soluble and to convert starches into fermentable sugars and proteins into peptides and amino acids. Since each of the enzymes involved in these chemical reactions act within narrow optimum temperature and pH ranges, mashing involves closely controlled time and temperature conditions. In any specific brewery mash, the times, temperatures, and materials ratio are precisely specified and controlled to achieve repeatability in the process and uniformity in the product.

The single most widely used mashing process in North America is called a double-mash, upward infusion system. This system uses a cereal cooker in which the adjuncts are boiled and a mash tub in which the malt mash is prepared and in which the cooker mash and malt mash are combined.

The first step is the mashing-in or doughing-in, of a small quantity of crushed malt in hot water in the cereal cooker. A typical malt charge for the cereal would be 5% to 10% of the cereal used. The temperature of the mash water, or foundation water, is between 100° F and 122° F. The cooker malt mash is allowed to rest or is mixed gently for a “rest” period of 15 to 30 minutes. The purpose of this “peptonizing” rest is to soak the ground malt, physically liberating the starches and proteins and activating the enzyme systems which were developed during malting.

At the end of the peptonizing rest, adjuncts and hot water are added to the cooker. Heat is applied to the mash to begin a gradual rise to boiling temperature. During this rise from peptonizing to boiling, two major actions take place consecutively. First, the adjunct starch granules gradually absorb water and swell to several times normal size, thickening the mash to a gelatinized consistency. This is called the “gelatinization” of the starch.

In the presence of the malt enzymes, particularly alpha amylase, the second major action takes place at about 185° F when the water-swollen starch granules rupture and the starch molecules disperse throughout the mash. This is called the “liquefaction” of the starch. Following liquefaction, the mash is boiled for a period which depends upon the specific adjuncts being used. Complete liquefaction of the cereal starch is essential to ensure complete conversion of the starch later in the mash tub.

The preparation of the malt mash proceeds concurrently and partially overlaps the preparation of the cooker mash. About the time the adjuncts are being added to the cooker mash, the malt for the malt mash is mashed in hot water to begin a peptonizing rest. The mash also goes through a protein rest at approximately 122° F. During this protein rest, proteolytic enzymes break down large and intermediate molecular weight proteins into smaller, more soluble substances.

The two mashes are scheduled so that the completion of the required boiling time of the cooker mash coincides precisely with the completion of the protein rest of the malt mash. The cooker mash is then transferred into the malt mash. During the transfer and immediately following, the malt enzymes alpha-amylase and beta-amylase convert the starches into fermentable sugars, principally maltose, some unfermentable sugars, and some unfermentable dextrins. The brewer’s control of time and temperature determines the proportion of maltose and dextrins which are produced, which in turn determines the degree of fermentability of the wort. A greater production of maltose results in a higher alcohol content. The unfermentable dextrins remain as extract in the finished beer, contributing to the body and flavor.

After the combined mash has reached conversion temperature, it is mixed gently until conversion is completed. Mashing ends when starch conversion is complete. This is indicated by the absence of a color reaction when samples of the wort are treated with a diluted iodine solution. The temperature is raised to “mashing-off” temperature (167 to 170° F) to inactivate the enzymes. The mash is then ready for lautering or filtration.

Brewers are currently practicing high gravity brewing. In high gravity brewing, wort is produced and fermented at substantially higher original gravity than the calculated original extract of the resulting beer. High gravity beer is usually blended with water prior to bottling to produce regular beer. High gravity brewing allows increased production without capital investments, since you get more beer from the same equipment.

Wort Separation

The removal of the wort from the mash solids is termed lautering. Three methods –using a Lauter Tub, Strainmaster, or Mash Filter – are common today; which one is used at a particular brewery is a matter of brewer's choice, tradition, or, in the case of multiplant breweries, company policy.

All of the lautering methods have the same objectives, the efficient delivery of highly clarified wort to the brew kettle, and all operate using the same basic principles. The cloudy wort is circulated through the filter bed of undissolved grain hulls and fiber until it becomes clear, when it is allowed to run off to the brew kettle. In a process called "sparging" hot water is then sprayed over the grain to wash off the remaining extract. The dilute wort is also run off to the kettle. Sparging will continue until saccharometer tests of the increasingly watery wort shows that almost all of the extract has been removed. Some brewers use the last wort from lautering operations as either foundation water for subsequent brews or as "cushion" water under the lauter tub plates. Finally, after sparging, the spent grains are removed; usually they are either dried or transported wet for use as animal feed.

Lauter Tub

The lauter tub is a vertical cylinder of a large diameter to depth ratio. It has a false bottom of precisely slotted stainless steel or brass plates. The plates fit together to form a flat and level floor upon which the mash comes to rest. Fitted into the bottom of the tub is a wort collecting system of pipes through which the wort is delivered to a collecting vessel called a grant. The wort and spargings can be observed and sampled as they run through the grant. The lauter tub has revolving blades or rakes which mix, loosen and level the grain bed. It is also equipped with a sparging system for hot water delivery.

Mash Filter

Although lauter tubs are probably the most widely used equipment for wort separation in North America, many of the large volume brewers use mash filters. A mash filter consists of a series of alternating plates and hollow frames suspended on side rails in a heavily constructed frame. The filter medium is a rectangular cloth which is draped over the top of the filter frame and down both sides. Modern mash filter cloths are generally made of polyethylene or polypropylene fiber. The mash fills the voids in the frames. When the mash is all in, the wort collection system is opened and the wort is drawn from the mash horizontally through the filter cloths. It flows downward along the plates and out through valves into the wort collecting trough or pipe.

Strainmaster

This system, a patented development of Anheuser-Busch, Inc., is said to incorporate the major advantages of both lauter tub and mash filter. Wort withdrawal is accomplished through a system of perforated tubes which transverse the lower third of the vessel. Wort withdrawal and circulation is initiated when the top row of tubes is covered. Wort runoff to the kettle is by gravity.

Wort Boiling with Hops

After lautering, the clarified wort is vigorously boiled for 1½ - 2 hours in the brew kettle. Brew kettles are large vessels made either of copper or stainless steel and available in various shapes and designs. They are covered by a high dome and are vented to permit the escape of vapors through a wide pipe rising to the brewhouse roof. Some kettles are equipped with agitators. The heating system is usually steam, although one major U.S. brewer uses direct fire to heat the kettle.

Boiling the wort accomplishes several things. First and most obvious, it concentrates the wort. Since the amount of water used to make the mash and sparge out the extract usually produces a wort of a gravity lower than desired, the wort must be concentrated by evaporation. A vigorous boil, with an evaporation rate of between 5-10% of the wort volume in an hour, will normally achieve the desired gravity, or balling.

The boiling process also gives the wort biological, biochemical, and colloidal stability. Boiling sterilizes the wort (sterilization is also aided by the antiseptic qualities of the hops), and destroys any enzymes that may have survived the final mashing temperature. In order to enhance shelf life, unstable colloidal proteins must be coagulated and precipitated for subsequent removal. This “kettle break” or coagulation is influenced by the duration and vigor of the boil as well as other chemical factors. ‘

Finally, boiling the wort develops flavor. Volatile flavor compounds derived from barley and the malting process are boiled away, and other ingredients are added to improve the taste. Common salt added to the boiling wort produces a fuller, richer flavored beer and helps in forming a good kettle break. Sugars, syrups, and caramel colors may be added as the wort runs into the kettle to insure thorough mixture. Hops however, are the most vital and influential ingredient in flavor development. The major flavor contribution they impart to the beer is a clean, dry, non-lingering bitterness.

If dry unprocessed hops are used, they must be removed from the wort upon completion of boiling. The boiled wort passes through a hop strainer or separator. This consists of a primary screen or slotted plates through which the bulk of the wort flows. The spent hops are retained on the screen, or are forced onto another set of screens from which they are removed by belt or conveyor. If hop pellets or hop extracts are used, no hop strainer is necessary. The wort can be pumped directly from the brew kettle to the hot wort tank.

Wort Cooling

The wort coming from the brew kettle is nearly boiling; before it can be fermented, it must be reduced in temperature to approximately 50° F. The wort must also be aerated, since some air is necessary for yeast to grow, and, finally, the wort must be further clarified.

In most breweries, the hot wort tank is used to draw off the clear wort from the trub (an amorphous mass of coagulated protein compounds). Hot wort tanks can be equipped with a special wort draw-off arm, or they may work according to the Whirlpool principle. In the Whirlpool principle, solid particles suspended in a rotating mass of liquid will migrate to the center and bottom of the tank. By pumping the wort into the tank the whole mass rotates and trub flocs migrate to the bottom center where this sediment is removed. The trub may also be removed by filtering or by centrifugation.

From the hot wort tank the wort passes to the cooler room. Generally, there are two types of coolers: open coolers which expose the wort to the surrounding air, and closed coolers. The most common type of open cooler is the Baudelot cooler. In the Baudelot cooler the wort runs down a series of horizontal tubes into the receiving pan. The cooling medium passes through the inside of the tubes. In the Baudelot cooler the wort is in contact with air during the cooling. With closed coolers, such as a double pipe cooler or a plate-type cooler, the wort is usually aerated sometime during the cooling process by injecting sterile compressed air into the flowing wort. The wort, as it comes from the brew kettle, is sterile, and will remain so down to about 145° F. -Below that temperature any bacterial or other organisms that the wort might pick up will remain alive and may cause the beer to spoil. Wort cooling should therefore bring about a rapid temperature reduction, and the cooling wort should be protected from contamination as much as possible to minimize the threat of microbiological infection. After cooling and aeration, the wort is ready for fermentation.

Fermentation

Fermentation is the third enzymatic system in beer production. Simply explained, yeast converts the fermentable sugars into alcohol and carbon dioxide and the wort becomes beer. However, fermentation is a complex process involving numerous enzymes and co-enzymes acting upon all of the fermentable carbohydrates or extract present in the wort. Numerous by-products develop during the fermentation and many components of the wort are assimilated by the yeast. These all have an impact upon the flavor and characteristics of the final beer.

Fermentation is largely dependent upon wort composition (nutrients for the yeast), the yeast itself, and the processing conditions. The brewer controls these three elements to determine the outcome of the beer. The major variables of wort composition which influence fermentation are the presence and concentration of various nutrients, pH, degree of aeration and temperature. The brewer selects yeast types and/or strains by their biochemical and physical behavior. This selection determines the fermentation pattern. Also, the amounts and methods of yeast addition (called pitching), the viability of the yeast, and the distribution of the yeast in the wort influences the fermentation.

The actual fermentation process (including time, temperature, volume, pressure, tank shape and size, and agitation of the fermenting wort) varies from brewery to brewery.

Most brewers in North America - probably over 80% - do not actually use starting settling tanks. Those who do use them believe they result in a purer fermentation, cleaner yeast crop, and improved beer flavor. The yeast may either be pumped into the wort transfer line or added directly to the fermenters or starting tanks.

Pitching usually takes place immediately after cooling since the cold wort may easily be contaminated. The normal pitching rate is 1-1 ½ pounds of liquid yeast per barrel of wort. However, the pitching rate depends upon the specific gravity of wort, temperature profile, and the desired rate of fermentation. With high gravity brewing, more yeast will have to be added.

Krausen Formation

Fermentation sets in within a few hours. Within 10-20 hours of pitching, the wort is covered by fine foam which changes to a thick voluminous creamy-white foam as time passes. This foam layer is called “krausen”. The high krausen period is the stage of most rapid fermentation. During fermentation heat is generated as a by-product. Since the wort must be maintained at a constant temperature, devices known as attemperators are used to control the temperature.

Carbon Dioxide gas is also generated as a byproduct of fermentation. The carbon dioxide is collected, purified, compressed and liquefied for storage in a pressure tank. Whenever the brewing process demands the use of carbon dioxide gas, the liquid carbon dioxide is passed through an evaporator and is piped in gaseous form to the user area.

When the yeast has converted most of the fermentable extract, the krausen begins to collapse. The yeast flocculates and settles to the bottom of the tank. The temperature drops and with the cooling of the "green beer" or "ruh", fermentation ceases. The green beer is then transferred to the storage cellar and kept at low temperatures. The yeast, which had settled out at the end of fermentation, is then recovered to be used in pitching subsequent brews or to be sold as a byproduct. Brewer's yeast is used as supplement in human diets and in animal feeds.

Losses Incurred

During normal fermentation the yeast will multiply from 3 to 5 times its original volume. Since only a portion of this is used for pitching another fermenter, the remainder contributes to operational loss through beer entrapped in yeast. Also, the filling and emptying of the fermenter and the transferring by pipeline cause some beer losses. Commonly reported loss figures are 2% to 3% of wort volume entering the fermenter. The losses may be reduced by the use of fermenters which remove yeast from under the beer or the use of separation equipment such as a centrifuge or a filter which recovers beer trapped in the yeast.

Quality Control

During fermentation, strict quality control is enforced. Time, temperature, pH extract and alcohol content values, flavor analysis, and yeast cell concentrations are checked. In order to preserve the purity of the yeast and to insure consistent product quality, brewers propagate pure yeast cultures in scrupulously clean and sterilized environments. In a typical procedure, the process starts with a master culture kept in the yeast bank. It is used to inoculate cooled sterilized wort. The yeast is allowed to multiply under controlled conditions until enough yeast is obtained to pitch a full brew. The brewery lab maintains detailed records of yeast generations used in each fermentation.

Cellar Operations

From the fermenting tanks the ruh beer is pumped to storage tanks. The terms "storage" and "lagering" describe the process of holding beer in a tank at refrigerated temperatures for a period of time after fermentation. Storage is not essential for beer production; however, the character of beer that has not been stored differs considerably from lager beer.

The most important function of storage is flavor maturation. During maturation some of the chemical constituents increase, some decrease and some remain the same. The chemical and biochemical reactions which take place in beer to bring it from its green fermented state to fully matured flavor are not completely understood.

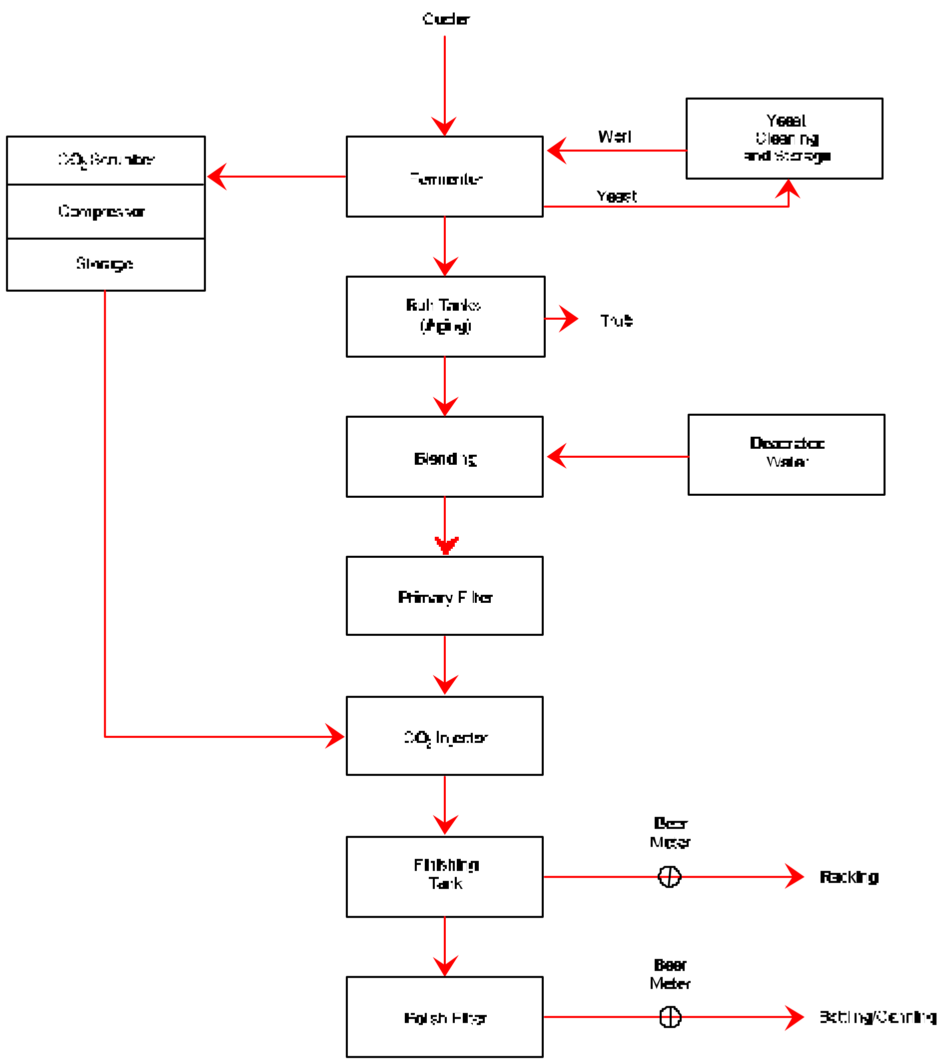
Secondary Fermentation

In some breweries, secondary fermentation will be carried out in the storage cellar. This can be achieved by a number of methods. The wort can be transferred close to, but before, completion of fermentation.

Secondary fermentation can also be achieved by using a two-yeast system, a combination of non-flocculent and flocculent yeasts. The non-flocculent yeast is carried over into the aging tank. Another technique is the addition of small portions of fermenting wort to the ruh beer or adding plain wort or a sugar solution with some yeast. This method, called “krausening”, gives the final beer different flavor and physical stability characteristics.

The other processes which occur in the cellars include carbonation, chillproofing and stabilizing, clarification, and standardization.

Cellar Operations



Carbonation

Traditional carbonation occurs during secondary fermentation in the storage tank. However, few breweries now rely on the traditional technique for the entire carbonation requirements. Mechanical techniques, including in-line carbonation, in-tank carbonation, saturation systems, or continuous counter-current diffusion, are used to collect the carbon dioxide naturally produced during fermentation. The carbon dioxide is reinjected into the beer later on in the process

Chillproofing and Stabilizing

Because beer has a tendency to become cloudy at chilled serving temperatures, chillproofing agents are used. This cloudiness, an insoluble colloidal haze, is due to various high molecular weight proteins and tannins combining. The chillproofing techniques attempt to either remove the protein and/or tannin or render it incapable of combining. These processes include the use of enzymes (papain), tannic acid, adsorbents (PVPP, nylon 66, bentonite, silica gel), and improved brewhouse procedures.

In addition to colloidal stability, the storage process is used to improve flavor stability and foam stability. The flavor stability of beer can be improved by a long (up to eight weeks) cold period of storage. However, since most beer is only stored up to 28 days, flavor stability can also be enhanced by the use of anti-oxidants such as KMS (potassium metabisulfite). In the process of making beer, oxygen becomes dissolved in it. In time, oxidation takes place and this can harm the flavor. The anti-oxidants interfere with the process of oxidation. The addition of foam retention agents encourages the formation and persistence of foam.

Clarification

After fermentation, beer is highly turbid with the presence of yeast, protein and tannin. The beer must be clarified to make it sufficiently brilliant to market.

Processing techniques include:

- Gravity sedimentation
- Fining agents
- Centrifugation
- Filtration

Gravity Sedimentation

During storage at temperatures close to freezing, most of the yeast and turbidity will settle to the bottom of the tank if fermentation has stopped and the tank is under counter-pressure.

Fining
Fining agents added to the storage tank accelerate the rate of sedimentation. Agents include bentonite, tannic acid, Irish Moss, silicates, silica gel.

Centrifugation
A centrifuge is a rotating container which separates the solids from the liquid using centrifugal force.

Filtration
Even if the above processes are used, the beer is usually filtered at least once at the end of the storage process prior to packaging. The beer may be filtered once from ruh storage into finishing tanks (primary filtration) and again prior to packaging (polishing filtration). Various filtration techniques include diatomaceous earth filtration, sheet filtration and pulp filtration.

Standardization

The beer must be blended to maintain a consistent product. Not only are brews blended with each other for consistency, but now with high gravity brewing the beer is blended with deaerated water for proper dilution. Additional equipment has been added for this process including water deaerators, water/beer ratio controllers, and metering equipment. The water is deaerated so that oxygen is not added to the beer being blended. The deaerated water can be carbonated or directly blended with the beer and that product carbonated. Normally, blending occurs after ruh storage. The blended beer is then placed into a finishing tank where final pre-packaging quality checks are made.